Graincast: near real time wheat yield forecasts for Australian growers and service providers

Zvi Hochman[1] and Heidi Horan[1]

[1]CSIRO Agriculture and Food, Queensland Bioscience Precinct, 306 Carmody Road St Lucia QLD 4067, Australia
http://research.csiro.au/graincast/wheat-yield-forecasts/; Zvi.Hochman@csiro.au

Abstract
Australia's climate is highly variable, with lower mean rainfall and higher rainfall variability than most other nations (Peel et al. 2004). Consequently, Australia's national wheat yields have varied over the last 30 years from 0.91 to 2.72 t/ha (mean=1.74; Coefficient of Variation = 0.22). This variability is problematic for the whole agricultural value chain and we propose that a client-centred and reliable yield forecasting system would improve the productivity of agribusiness in Australia. In this paper we describe the Graincast wheat yield forecasting system at the national scale and evaluate its performance in hindcast over the thirty-year period from 1987 to 2016. Over this period, the final forecast (issued on the 31st of December) had a root mean square deviation (RMSD) of 0.15 t/ha with a coefficient of determination (R^2) of 0.84 and very little systematic bias (slope = 1.06). The forecast uncertainty, as expressed by the median coefficient of variation (CV), of this probabilistic forecasting system declined progressively from 30th April (0.19), through 31 July (0.14), 31 August (0.10), 30 September (0.05) to 31 October (0.01) as more of the seasonal conditions were revealed.

Keywords: APSIM, strategic decision making, grain yield forecast, hindcast

Introduction

Climate variability drives yield variability, and this is the major factor that limits investment in the Australian agricultural sector (Allens 2014). It follows that having access to reliable seasonal forecasts of crop yields is highly valuable to stakeholders such as farmers, commodity traders, and government officials when making strategic decisions. The agribusiness sector closely follows several national and international services that provide forecasts of Australia's wheat yield at state to national levels. However, these forecasts are produced at arbitrary time intervals and are not scaled to meet specific clients' needs. Graincast is an APSIM (Holzworth et al. 2013) based yield forecast system that is flexibly scalable from a single paddock (as per the Graincast App) to the national level. Graincast has been producing fortnightly updated wheat yield forecasts from mid-April until harvest over the 2017 and 2018 wheat seasons. In this paper we describe the national Graincast forecasting system and evaluate its performance in hindcast over the thirty-year period from 1987 to 2016.

The graincast system

Graincast can be described as a series of steps that lead to a yield forecast at any time and scale. Here we focus on fortnightly wheat yield forecasts issued between mid-April and the end of December at the national scale. However, the same principles are applicable for any time interval and at greater granularity to state, regional, statistical local areas (SA2) and individual paddock scales. The steps taken to achieve a forecast may be summarised as: 1. identify representative weather stations that capture the variability of climate over the area of forecast; 2. assign to each of the selected weather stations its dominant soil type; 3. specify best management practice including wheat variety, fertiliser application, time of sowing, tillage and seeding rate; 4. use the above information as input into APSIM to first simulate current conditions using historic data to date (nowcast) and then using weather data from the previous 30 years to forecast a probabilistic range of water-limited yield outcomes that may eventuate at harvest (forecast); 5. convert simulated water-limited yields to yield forecasts by applying the calculated time trend that exists between the average water-limited yields at the selected weather station and the actual national average yields (Hochman et al. 2017).
The results of the thirty-year simulations are then presented progressively on a fortnightly basis as a series of yield probability columns where the more likely outcomes are illustrated by darker shades of green. The national forecasts issued in 2018 are illustrated by Figure 1.

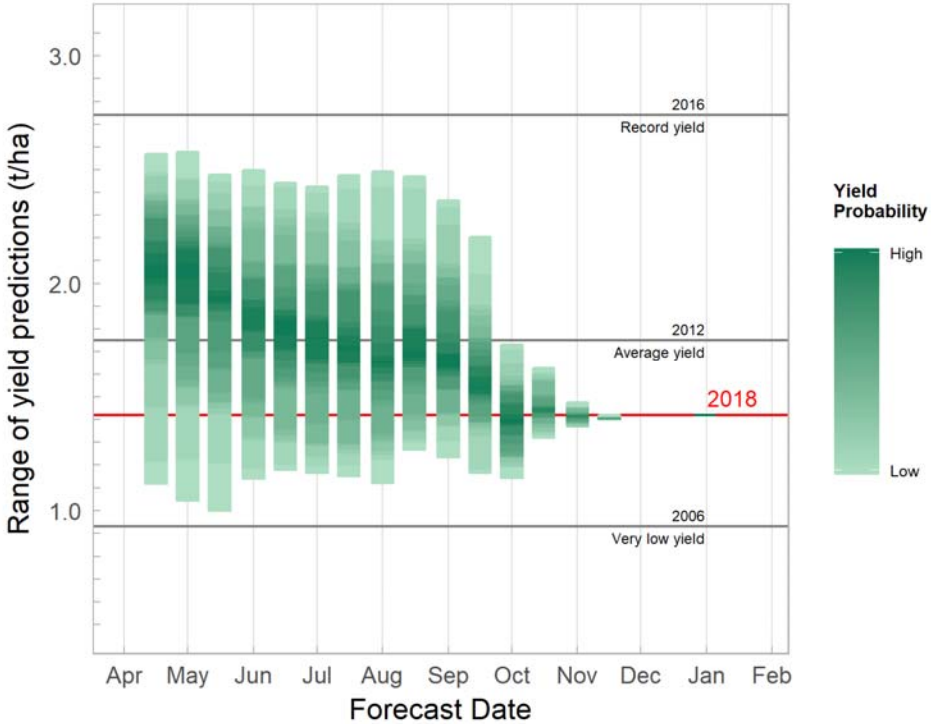

Figure 1. Progressive, bi-monthly, probabilistic national wheat yield forecasts issued during 2018. Each green band shows the yield forecast at the date indicated on the horizontal axis. They show, on the vertical axis, the whole range of possible outcomes with the most probable indicated by the darkest green shading. The red line shows the expected median value for the current year's yield on 31 December.

System evaluation

The annual actual national average yield (Ya) data were sourced from ABARES. These are compared in Figure 2 to the forecast yields as predicted on the 31st of December of the same year.

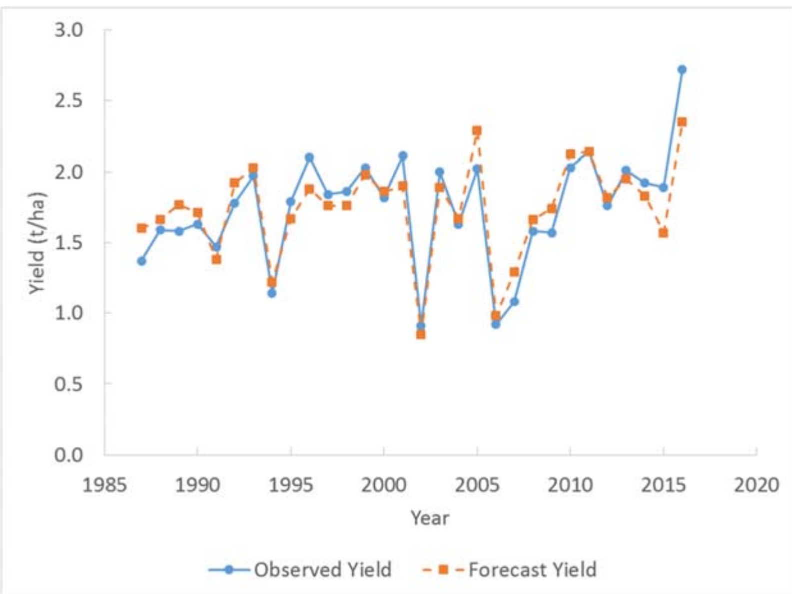

Figure 2. Historic evaluation of Graincast yield forecasts compared with ABARES yields estimated from 1987 to 2016.

Analysis of these data showed that the forecast yields were closely correlated to the observed yields:

Observed Yield = 1.0553 x Forecast yield - 0.096 (R^2 = 0.84; RMSD = 0.15).

The value of a forecast depends not only on its ultimate accuracy but also on its timeliness. Thus, an accurate forecast in April is more valuable than an equally accurate forecast in August, which in turn more valuable than an equally accurate forecast that is made in November. The tradeoff between timeliness and uncertainty of forecasts is illustrated by the size of the green bars in the sequential probabilistic forecasts made at the end of the months of April, July, August, September, October, November and December for over the 30 years from 1998 to 2016. In figure 3 we present six of the 30 annual forecasts to illustrate the variety of forecast developments that were observed over different seasons.

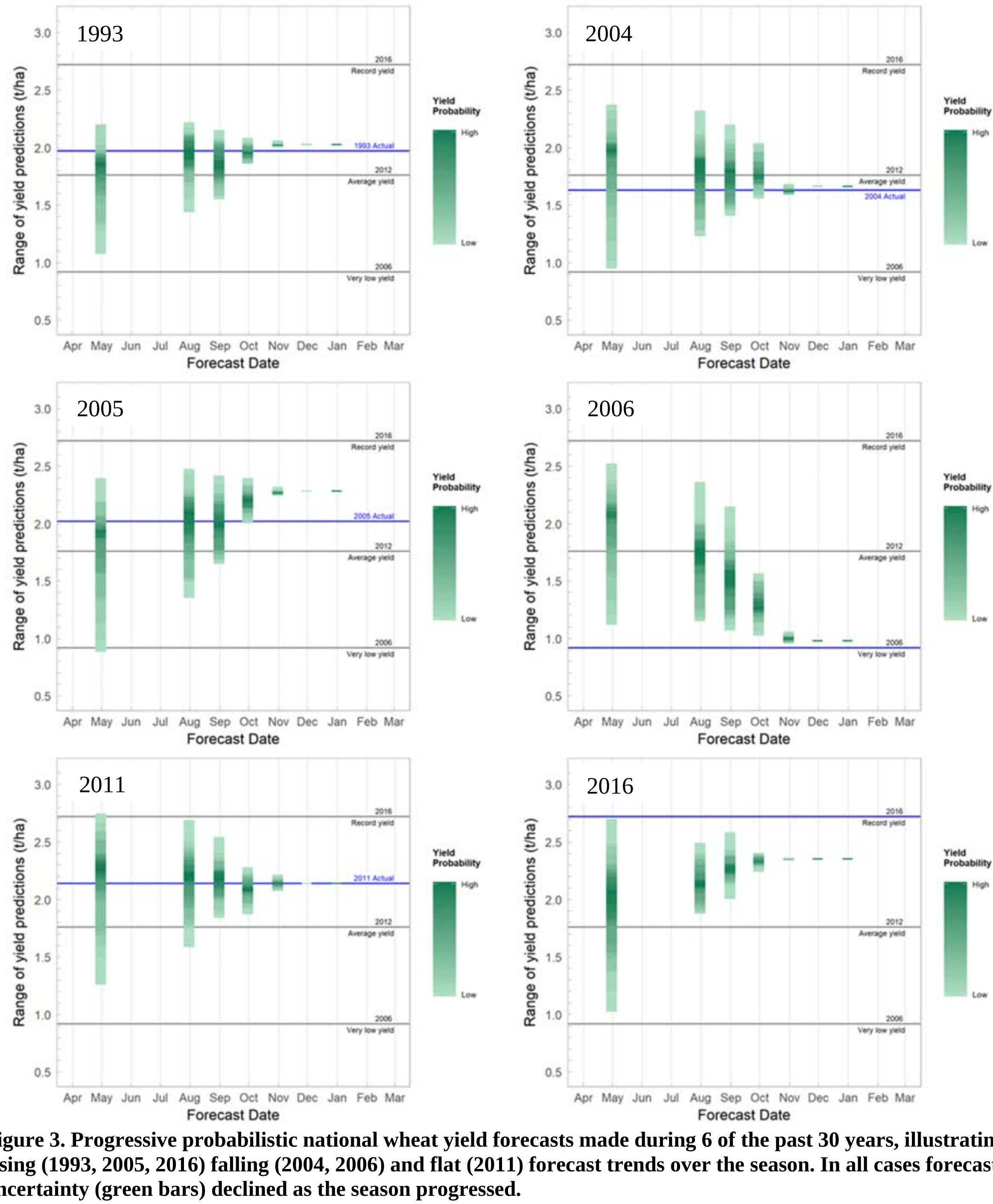

Figure 3. Progressive probabilistic national wheat yield forecasts made during 6 of the past 30 years, illustrating rising (1993, 2005, 2016) falling (2004, 2006) and flat (2011) forecast trends over the season. In all cases forecast uncertainty (green bars) declined as the season progressed.

As the season develops and more of the season's conditions become apparent we can expect that uncertainty about the final grain yields will reduce. This uncertainty can be expressed in terms of the coefficient of variation (CV) of the mean forecast at each time of forecast. The decline in CV from the end of April to the end of December is illustrated in Figure 4. While year to year variations are important, the median CV value drops emphatically from 30th April (0.19), through 31 July (0.14), 31 August (0.10), to 30 September (0.05) and 0.01 by the 31st of October as crop maturity is approaching at most of the 50 sites. Zero uncertainty does not mean that the prediction is 100% correct but rather that the prediction is subject only to model and data error rather than uncertainty about the impact of future weather conditions on yields.

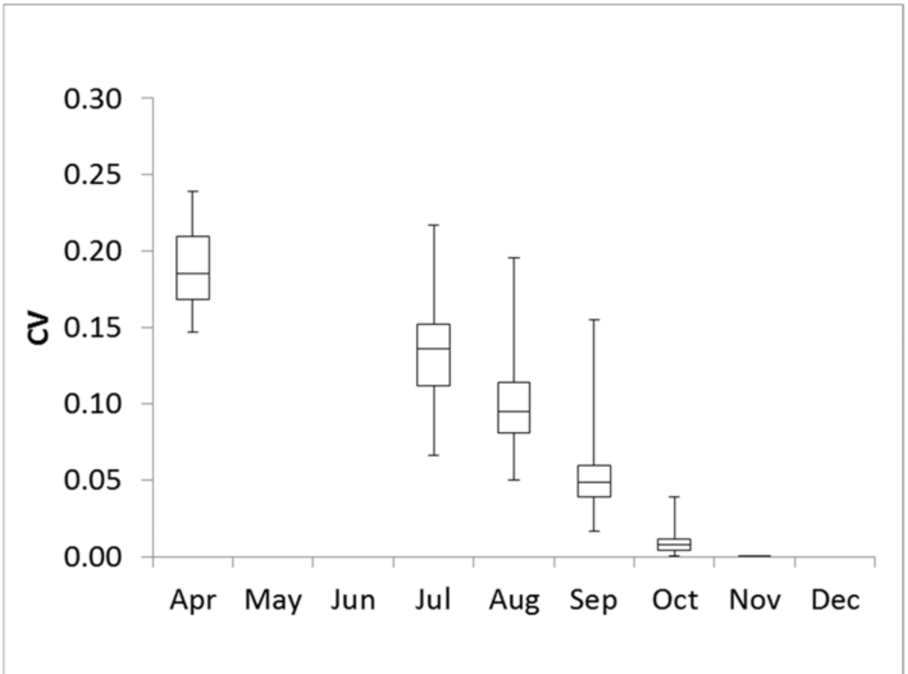

Figure 4. A time series of uncertainty of predictions of Australia's wheat yield forecasts from 1987 to 2016. Uncertainty is expressed as boxplots (showing minimum, 1st quartile, median, 3rd quartile and maximum values) of the coefficient of variation (CV) around the median prediction.

Conclusion

This research demonstrates that Graincast provides a reliable (RMSD = 0.15 t/ha) and unbiased estimate of wheat yield for Australia at a national level. Forecast uncertainty is large at the end of April (CV= 0.19 compared with CV=0.22 for observed data) but declines with each month such that by the end of September it is down to 0.05. Forecast improvement can be achieved by more accurate calculation of the final yield and/or by reducing prediction uncertainty earlier in the season. Further work will target the accuracy issue by improved specification of APSIM to better reflect current best management practices. The uncertainty issue will be addressed by incorporating seasonal climate forecasting and assessing its impact on reducing forecast CV values earlier in the growing season. We also intend to engage interested stakeholders to determine if and how they may derive value from these forecasts.

References

ABARES, 2015. Agricultural commodity statistics 2015. CC BY 3.0., Canberra, Australian Bureau of Agricultural and Resource Economics and Sciences.

Allens Agribusiness Survey (2014). https://agwhitepaper.agriculture.gov.au/sites/default/files/SiteCollectionDocuments/GP194%20Allens.pdf Last accessed 01 March 2019.

Hochman Z, Gobbett DL and Horan H (2017). Climate trends account for stalled wheat yields in Australia since 1990. Global Change Biology, 23, 2071-2081.

Holzworth, D.P., Huth, N.I., deVoil, P.G., et al. (2014) APSIM – Evolution towards a new generation of agricultural systems simulation. Environmental Modelling and Software. 62, 327-350.

Peel MC, McMahon TA and Finlayson BL (2004). Continental differences in the variability of annual runoff: update and reassessment. Journal of Hydrology, 295, 185–97.